PATENT SPECIFICATION

DRAWINGS ATTACHED

Inventor: JOHN FRANCIS WAHL

868,934

Date of Application and filing Complete Specification: July 1, 1957.

No. 20649/57.

Complete Specification Published: May 25, 1961.

Index at acceptance:—Classes 35, A1B2(D: J), A4X; and 131, M6B.

International Classification:—H02k. B26b.

COMPLETE SPECIFICATION

Vibratory Electromagnetic Motor

We, WAHL CLIPPER CORPORATION, a corporation organized and existing under the laws of the State of Illinois, United States of America, of 411 East Third Street, Sterling, State of Illinois, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a vibratory electromagnetic motor.

Vibratory electromagnetic motors are used extensively to power small hand tools such as hair clippers and dry shavers. For convenience, the present motor will be described in connection with a hair clipper, but it is understood that the motor may be used in other apparatus.

Conventional vibratory electromagnetic motors have an electromagnet comprising a coil and associated core energized by a current of fixed frequency, for example, 60 cycles. A vibratory armature, mounted in spaced, effective relation with the core, drives a work element as for example the movable blade of a hair clipper. The armature, which forms a part of the magnetic circuit of the electromagnet, moves (vibrates or oscillates) in response to the varying magnetic field of the electromagnet, the permeability of the magnetic circuit varying with the movement path of the armature.

The natural tune frequency of the vibratory armature corresponds generally to a multiple of the frequency of the applied voltage, the two frequencies (natural tune of armature and voltage multiple frequency) being somewhat different in order to control the amplitude of armature vibration and to provide usable power. Usually the natural tune frequency of the armature is substantially twice the voltage frequency, the multiple being two, although other multiples are possible.

A conventional motor of the aforesaid character has certain inefficient and undesirable characteristics, as will be seen. For example, under no load condition the maximum instantaneous magnetic pull exerted on an undertuned armature occurs when the armature is near the point in its travel path which is most remote from the core. This point may be referred to as the "out" position of the armature. At the "out" position the space or gap between the core and the armature is a maximum. Because the gap is a maximum, a relatively high value current peak is required to force the maximum-pull flux across the gap. In view of this condition the power consumption of a conventional motor is relatively high and such motors must be larger and heavier than desirable.

When substantial load is encountered by a conventional electromagnetic motor, the armature amplitude is reduced and the power delivered by the motor decreases substantially. The watts input decreases at least 25% when the motor is stopped completely by a load. Thus, a conventional motor which draws eight watts when operating freely draws about six watts when operation stops due to excessive load. This poor power performance is particularly undesirable in hair clippers since the static friction between the lapped blade surfaces is high, and is a constant source of difficulty.

A conventional vibratory motor thus is inefficient in that when operating freely the watts in put is substantially a maximum and when stalled, a minimum. Such a motor, therefore, must be designed for adequate heat dissipation based on heat developed during free or no load operation. The shortcomings of the motor are accentuated by the decrease in mechanical power delivered and by the decrease in watts input experienced when the motor encounters substantial load.

The present invention comprises a vibratory electro-magnetic motor which effectively overcomes the aforesaid shortcomings of the

conventional motor. The improved motor draws a minimum current under no load and a maximum current under full load. When operating freely under no load, the motor develops a maximum instantaneous magnetic pull on the armature when the armature is at the point in its travel path which is nearest to the core. This point may be referred to as the "in" position of the armature. At this time the instantaneous current in the coil is close to maximum, but the space or gap between the core and the armature is a minimum. Because the gap is a minimum, only a relatively low value current peak is required to force the maximum-pull flux across the gap. Thus the average current and watts input are relatively low. This may be compared with the relatively high value current peak and high watts input required in a conventional motor wherein the maximum-pull flux occurs when the armature is "out" and the gap between the armature and the core is a maximum.

In addition, the operating characteristics of the improved motor are such that when mechanical load is encountered the power capabilities of the motor increase spectacularly. When near full load the motor delivers at least 100% more power than a conventional motor with the same normal-operation heat ratings.

When load is encountered the watts input of the motor increases, this increase being as much as 50% under conditions of maximum load. Such power and watts input increases are not accompanied by excessive heating in a practical sense for the reason that motors of this type normally do not operate under load conditions for extended periods of time. As soon as the load is withdrawn, the watts input immediately decreases to a lower value.

Another improved characteristic of the present motor is that it operates without appreciable external vibration. Such a motor usually is incorporated in a manual appliance, e.g. hair clipper, dry shaver, etc., and freedom from external vibration is highly advantageous. In most conventional motors of this character external vibration is excessive and objectionable.

Still another improved characteristic of the present motor is that the effective stroke of the vibratory or oscillatory work delivering element can have a relatively large amplitude even though the air gap between the armature and core is desirably small, as will be seen.

This invention according to one aspect consists in a vibratory electric motor having an electromagnet constructed to be energised by an alternating current of fixed frequency, a vibratory armature possessing a resilient characteristic disposed in effective relation with said electromagnet, an undertuned vibratory work arm possessing a resilient characteristic connected to and driven by said armature, and a work element positively connected to and driven by said work arm, said work arm being rigidly connected at one end to the armature and having an end portion and or an intermediate portion extending alongside and spaced from the armature.

According to another aspect the invention consists in a vibratory motor having an electromagnet constructed to be energised by an alternating current of fixed frequency, a vibratory armature possessing a resilient characteristic disposed in effective relation with said electromagnet, a vibratory work arm possessing a resilient characteristic connected to and driven by said armature, and a work element positively connected to and driven by said work arm, said work arm being rigidly connected at one end to the armature and having an end portion and or an intermediate portion extending alongside and spaced from the armature, said vibratory resilient armature being constructed and mounted so as to possess a natural tune frequency of a value substantially different from the nearest multiple of said current frequency under a condition of no external load on said work element i.e. when the element is not engaged in a work performing action, e.g. a cutting action, whereby the vibration of said armature is characterised by small amplitude, said work arm being so constructed and mounted to said armature and work element as to possess a natural tune frequency substantially below said nearest multiple of said current frequency at a condition of no external load on said work element, increase of external load on said work element effecting a change in tune frequency of said armature toward reasonance with said multiple of said current frequency, thereby increasing the amplitude of said armature vibrations.

Other features, advantages, characteristics and details of the invention will be apparent as the description proceeds, reference being had to the accompanying drawings which illustrate certain characteristics of a conventional motor and of the improved motor as well as show one practical embodiment of the invention. It is to be understood that the description and drawings are illustrative only, and that the scope of the invention is to be measured by the appended claims.

In the accompanying drawings:

Fig. 1 is a diagrammatic illustration of a conventional vibratory electromagnetic motor;

Fig. 2 is a curve of instantaneous current plotted against time and which shows the related positions of the armature of the Fig. 1 motor, the curve being taken from a cathode ray oscilloscope;

Fig. 3 is an approximate curve showing the relationship between the power delivered by a conventional motor and mechanical load encountered by the motor;

Fig. 4 is an approximate curve showing the relationship between the watts input to a conventional motor and mechanical load encountered by the motor;

Fig. 5 is a diagrammatic illustration of a vibratory electromagnetic motor constructed in accordance with the present invention;

Fig. 6 is an oscilloscope curve of instantaneous current plotted against time and which shows the related positions of the armature of the Fig. 5 motor, the motor operating under no load condition;

Fig. 7 is an oscilloscope curve similar to that of Fig. 6, the motor operating under load condition;

Fig. 8 is an approximate curve showing the relationship between the power delivered by the motor of Fig. 5 and mechanical load encountered by the motor;

Fig. 9 is an approximate curve showing the relationship between the watts input of a Fig. 5 motor and mechanical load encountered by the motor;

Fig. 10 is a plan view with the housing cover removed of a hair clipper using a vibratory electromagnetic motor embodying the invention;

Fig. 11 is a bottom view of the hair clipper of Fig. 10, a portion of the bottom being cut away to illustrate certain details of the motor;

Fig. 12 is a sectional view on irregular line 12—12 of Fig. 10;

Fig. 13 is a diagrammatic illustration in front view of a modified motor constructed in accordance with the invention, and

Fig. 14 is a side view of a portion of the motor shown in Fig. 13.

Before describing the present invention in detail, it seems desirable to describe a conventional vibratory electromagnetic motor and refer briefly to its operating characteristics. In so doing, a better understanding of a motor embodying the invention and its improved operating characteristics will be obtained. Both the conventional motor and the motor embodying the invention will be described as applied to a hair clipper which, as is well known, has a stationary cutter blade and a cooperating movable cutter blade driven by a vibratory or oscillatory element of the motor.

Referring to Fig. 1, a conventional vibratory electromagnetic motor has a fixed coil 15 and a pole piece or core 16. A vibratory armature 17 is disposed in effective relation with core 16, an air gap 18 being present between the core and armature.

Armature 17 includes a resilient or elastic arm 19 which is anchored at 20 to a fixed support. The resilience of arm 19 is diagrammatically shown by spring convention 21. The free end of armature 17 actuates the movable blade 22 of a hair clipper.

The assembly of armature 17, including resilient arm 19, and work blade 22 has a predetermined natural tune frequency which corresponds generally to a multiple (usually 2f) of the frequency of the voltage applied to coil 15. A certain difference in these two frequencies is necessary in order to confine the armature amplitude within safe limits and to provide usable power. This requirement is well known in the art. As an example, the natural tune frequency of the aforesaid assembly may be 110 when 2f of the applied voltage equals 120.

Referring to Fig. 2, the cathode ray oscilloscope curve 25 illustrates the wave shape of alternating current drawn by coil 15. The distortions appearing in curve 25 at the ordinate positions designated *A* indicate positions in the path of armature travel where armature 17 is nearest core 16. These positions are referred to as the armature "in" positions. The armature "out" positions on current curve 25 are designated *B*. From Fig. 2 it will be seen that the instantaneous current is substantially a minimum when the armature is "in", and substantially a maximum when the armature is "out".

Maximum flux or pull, of course, occurs when the instantaneous current is a maximum, and it is inefficient for these conditions to occur when the armature is "out" and there is a maximum gap 18 between core 16 and armature 17. The condition is inefficient because a relatively high current peak is required to force the maximum-pull flux across the maximum gap. In other words, a relatively high average current is required to operate a conventional motor and a ceiling on this current is imposed by design considerations of heat dissipation and safety.

As previously mentioned, when a conventional motor encounters load its mechanical power output decreases significantly. This characteristic is illustrated by curve 26 in Fig. 3.

Fig. 4 illustrates by curve 27 the decrease in watts input with load in most conventional motors of this type. A drop of 25% usually occurs when the armature is stopped completely.

In addition to the aforesaid shortcomings, conventional motor operation ordinarily is accompanied by excessive external vibration. This is objectionable in those instances where the motor is used in a manual tool such as a hair clipper or dry shaver.

The improved vibratory electromagnetic motor of the invention is diagrammatically shown in Fig. 5, and Figs. 6—9 are curves illustrating various characteristics thereof so they may be compared with those of the conventional motor of Fig. 1.

Referring to Fig. 5, the improved motor has a fixed coil 30 and a pole piece or core 31. An armature 32 of appreciable mass is disposed in effective relation with core 31,

armature 32 including a resilient or elastic arm 33 mounted at fixed point 34. The resilience of arm 33 is diagrammatically indicated by spring convention 35. The space or gap between core 31 and armature 32 is designated 36.

Armature 32, including arm 33, has a natural tune frequency of vibration which is substantially different from a multiple frequency of the voltage applied to coil 30. Unlike armature 17 in the conventional motor, armature 32 in the improved motor does not directly engage and drive a work element, as will be seen.

The improved motor utilizes a second arm, namely arm 37, which is here called a "work arm". Work arm 37 has a resilient or elastic characteristic, as designated by spring convention 38, and it is mounted rigidly to armature arm 33 at an intermediate point 40. The free end of work arm 37 engages and drives the movable blade 42 of a hair clipper.

When the assembly of armature 32, work arm 37 and work blade 42 is operating freely under no load, armature 32 is forced to vibrate at a frequency (usually 120 cycles per second) which is a multiple of the frequency of the applied voltage. In this respect the vibration of armature 32 is like that of armature 17 in the conventional motor previously described.

Unlike the conventional motor armature, armature 32 has a predetermined natural tune frequency which is substantially different from a multiple of the frequency of the applied voltage. Thus armature 32 has an extremely small amplitude of vibration under no load.

When work blade 42 encounters a load, the natural tune frequency of armature 32 changes and approaches in value the multiple frequency of the applied voltage. Under this circumstance the amplitude of armature 32, instead of decreasing as in the case of the conventional motor, increases with the result that the mechanical power output of the motor increases spectacularly. This increase in mechanical power output under load conditions is, of course, highly advantageous.

In the motor shown in Fig. 5 the increased amplitude of armature 32 is limited by the space 36 provided between the armature and core 31. This limitation is reduced in a motor of modified design, as shown in Fig. 13, wherein armature 43, pivoted on shaft 43*a* oscillates back and forth with respect to pole faces 44 and 44*a* but can never engage them. In this modified arrangement, a resilient work arm 44*b* is rigidly connected to armature 43, the resilient characteristic of work arm 44*b* being shown by spring convention 44*c*. A work element 44*d* is carried at the free end of work arm 44*b*.

Referring again to Fig. 5, work arm 37 is driven in a vibratory manner by reaction to the vibration of armature 32. The direction of travel of work arm 37 is instantaneously opposite to that of armature 32. These opposing movements tend to cancel one another so far as external vibration are concerned, and hence a housing containing the motor is free of external vibration except when the motor is under heavy load and the armature is vibrating with large amplitude. Similar opposing movements occur with armature 43 and work arm 44*b* of the Fig. 13 modification.

Work arms 37 or 44*b* must have a natural tune frequency substantially below the nearest multiple of the voltage frequency in order to confine the amplitudes thereof to safe limits under no load conditions. In one specific example the work arm 37 had a natural tune frequency of 88 cycles per second under no load condition.

Under load conditions the presence of the work arm with its resilient characteristic has an effect on the tune frequency of the armature. In other words, a load produces a change in the armature tune frequency, so the new or load tune frequency is substantially different from the natural tune frequency under no load condition.

In Fig. 6, oscilloscope curve 45 shows the wave shape of current drawn by coil 30. The distortions appearing at the ordinates designated *A* indicate the points on the current cycles where armature 32 is at the points in its travel path closest to core 31. It will be noted that these distortions occur at or near the peaks in the current wave shape. This condition is to be compared with that of the conventional motor where the distortions occur at or near current minimums. Thus it will be seen that the improved motor when operating freely has a maximum flux or pull when the armature is "in". Inasmuch as gap 36 between core 31 and armature 32 is a minimum when the armature is "in", it will be seen that a much smaller average current is required to operate the improved motor under no load condition. Thus, the watts input to the motor is correspondingly low. By selection of armature 32 and work arm 37 from the stand point of natural tune frequencies it is possible to obtain the most desirable no load and full load operating characteristics.

It further will be noted from Fig. 6 that the current is substantially a minimum when the armature is "out", as indicated by the ordinates *B*. With the minimum current at these armature positions, minimum pull, of course, is exerted on the armature when the armature is "out" and maximum gap is present. This, of course, is a highly efficient condition of operation.

From the foregoing it will be seen that the

travel of the armature is efficiently in phase with the variations in the magnetic field so that a magnetic circuit of minimum reluctance is obtained. In other words, the instantaneous current is high when the armature is "in" and the gap is small, and the instantaneous current is low when the armature is "out" and the gap is large. This, of course, provides a high inductance circuit in the coil which keeps the average current and the watts input at low values.

As mentioned above, when work element 42 encounters a load the operating characteristics of the motor undergo certain changes, and there are changes in the relationships between the instantaneous current and the armature positions. A load applied to work element 42 shortens the amplitude of work arm 37 and introduces a change in the tune frequency of armature 32. This change is in the direction of the multiple of the frequency of the voltage applied to coil 30, and, as a result, armature 32 vibrates at a substantially greater amplitude than that prior to the application of the load to work element 42. The increased amplitude of armature 32 urges work arm 37 to continue to vibrate and thus develops an increased mechanical power output at work element 42. This increase is illustrated by curve 46 in Fig. 8, and the increase may be 100% or more.

In Fig. 7, curve 48 shows the relationship between the instantaneous current and the "in" and "out" positions of armature 32 when work element 42 encounters a load. The distortions in curve 48 at ordinates *A* designate positions in the armature path closest to core 31, that is, the armature "in" positions. It will be noted that these distortions occur when the instantaneous current is at or near a minimum. Similarly, the armature "out" positions occur when the instantaneous current is at or near a maximum. This change in relationship compared with conditions when the motor is operating freely reduces the inductance of the electric circuit and permits an increase in watts input, this input ranging to 50% or more. The curve 49 in Fig. 9 illustrates the increase in watts input with the increase in mechanical load encountered by the motor.

From the foregoing it will be seen that the improved motor operates with extreme efficiency under no load conditions. Consequently the motor, in terms of mechanical power output, can be designed within approved, safe limits of power consumption when operating under no load. Such a motor, when load is encountered, desirably delivers increased power and consumes increased watts input, compared with the opposite in the case of conventional motors. Also, conventional motors operate inefficiently under no load conditions and hence cannot be designed to have power output capabilities comparable to the present motor.

Figs. 10—12 illustrate an electric hair clipper having a motor embodying the present invention. The clipper includes a housing 55 having a stationary clipper blade 56 mounted at one end. Secured within housing 55 is an electromagnet comprising a coil 57 and an associated core 58.

An armature 60 having appreciable mass is mounted in effective relation with core 58, armature 60 including a resilient or elastic armature arm 61 which is secured to housing 55 at 62. The natural tune frequency of armature 60 is substantially different from a multiple of the frequency of the voltage applied to coil 57.

A resilient or elastic work arm 65 has end 66 rigidly mounted on armature arm 61 by screws 67. Work arm 65 extends generally below and parallel to armature arm 61. The forward end 68 (Fig. 12) of work arm 65 carries a bracket 69 which in turn carries a finger 70. Finger 70 engages a movable clipper blade 71 which is mounted for cooperative action with fixed clipper blade 56.

When coil 57 is energized by alternating current, armature 60 vibrates in response to the varying magnetic field of the electromagnet. As will be seen, armature 60 vibrates with small or medium amplitude when the clipper is operating freely, that is, when movable blade 71 does not encounter resistance. Work arm 65 is driven in a vibratory manner by reaction from the vibrations of armature 60, the work arm 65 traveling in directions opposite to those of armature 60. The opposing directions, of course, minimize or eliminate external vibrations in housing 55. Finger 70 on work arm 65 vibrates with substantial amplitude and drives movable clipper blade 71.

When movable blade 71 encounters resistance, the amplitude of work arm 65 decreases somewhat. This effects a change in the tune frequency of armature 60 and brings the tune frequency thereof considerably closer to a multiple of the frequency of the voltage applied to coil 57. In this condition armature 60 vibrates with increased amplitude and as a result the mechanical power delivered to movable blade 71 increases. In addition, as previously mentioned, the electromagnetic consumes increased wattage which aids in developing the increased mechanical power ouput.

From the above description it is thought that the construction and advantages of the invention will be readily apparent to those skilled in the art.

In view of Section 9 (sub-section 1) of the Patents Act 1949, the attention is directed to the claims on Patent No. 793,742.

WHAT WE CLAIM IS:—

1. A vibratory motor having an electro-

magnet constructed to be energised by an alternating current of fixed frequency, a vibratory armature possessing a resilient characteristic disposed in effective relation with said electromagnet, an undertuned vibratory work arm possessing a resilient characteristic connected to and driven by said armature, and a work element positively connected to and driven by said work arm, said work arm being rigidly connected at one end to the armature and having an end portion and or an intermediate portion extending alongside and spaced from the armature.

2. A vibratory motor having an electromagnetic constructed to be energised by an alternating current of fixed frequency, a vibratory armature possessing a resilient characteristic disposed in effective relation with said electromagnet, a vibratory work arm possessing a resilient characteristic connected to and driven by said armature, and a work element positively connected to and driven by said work arm, said work arm being rigidly connected at one end to the armature and having an end portion and or an intermediate portion extending alongside and spaced from the armature, said vibratory resilient armature being constructed and mounted so as to possess a natural tune frequency of a value substantially different from the nearest multiple of said current frequency under a condition of no external load on said work element i.e. when the element is not-engaged in a work performing action, e.g. a cutting action, whereby the vibration of said armature is characterised by small amplitude, said work arm being so constructed and mounted to said armature and work element as to possess a natural tune frequency substantially below said nearest multiple of said current frequency at a condition of no external load on said work element, increase of external load on said work element effecting a change in tune frequency of said armature toward reasonance with said multiple of said current frequency, thereby increasing the amplitude of said armature vibrations.

3. A vibratory motor as claimed in claims 1 or 2 characterized by said armature and said work arm respectively having masses which effectively counter-balance each other to eliminate external vibration.

4. A vibratory motor substantially as hereinbefore described with reference to Figs. 5 and 10 to 14 of the accompanying drawings.

MARKS & CLERK.

Leamington Spa: Printed for Her Majesty's Stationery Office, by the Courier Press.—1961.
Published by The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtained.

Fig. 1.

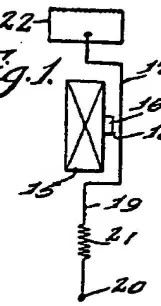


Fig. 13.

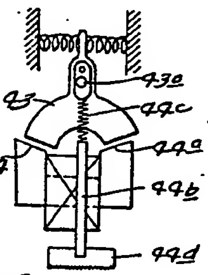


Fig. 14

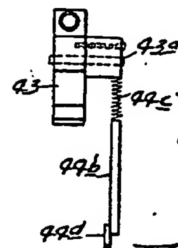


Fig. 5.

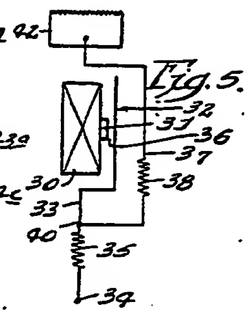
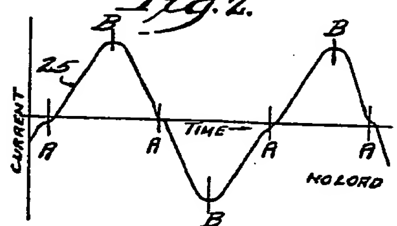
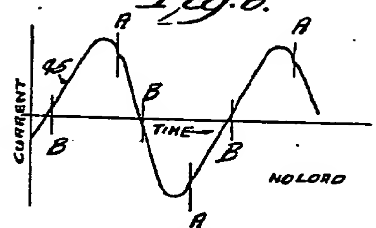


Fig. 2.



A-ARMATURE IN
B-ARMATURE OUT

Fig. 6.



A- ARMATURE IN
B- ARMATURE OUT

Fig. 3.

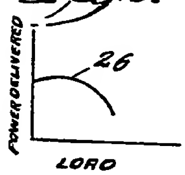


Fig. 8

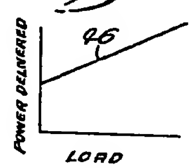
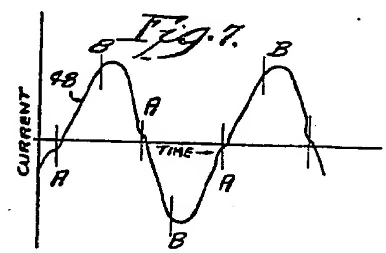


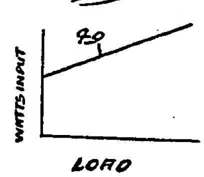
Fig. 7.



A- ARMATURE IN
B- ARMATURE OUT

Fig. 4.

Fig. 9.



868934 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheets 1 & 2

Fig.5.

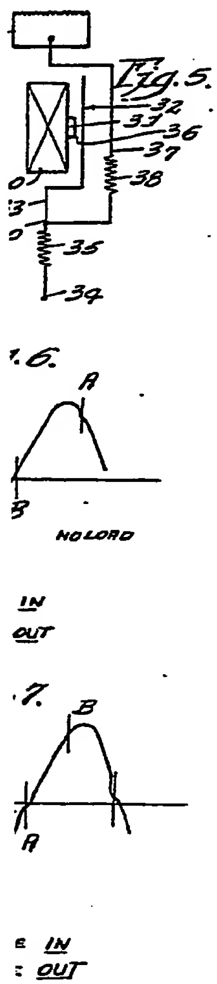


Fig.10.

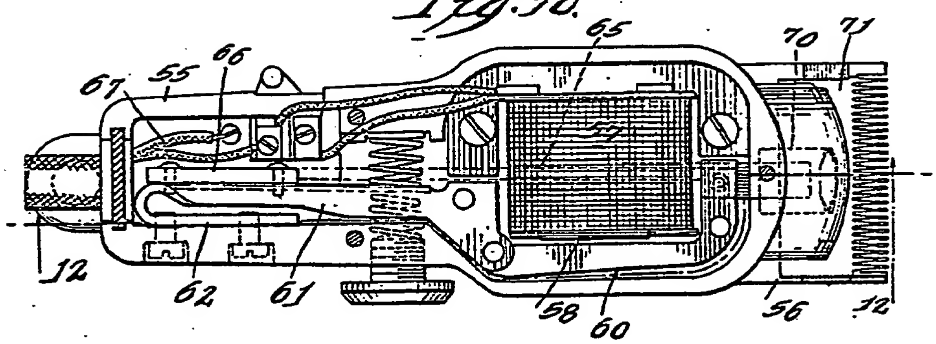


Fig.11.

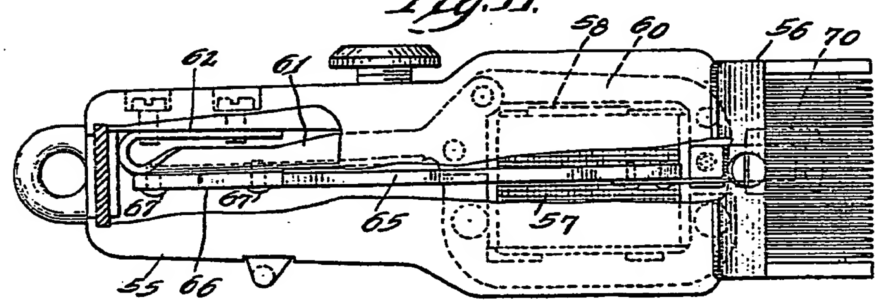
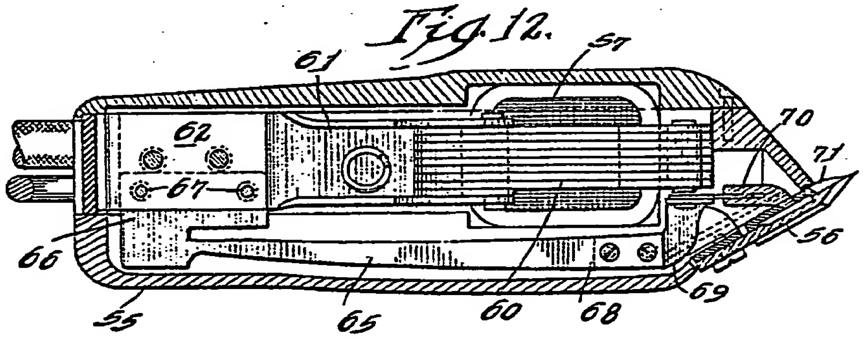


Fig.12.



868934 COMPLETE SPECIFICATION

2 SHEETS This drawing is a reproduction of the Original on a reduced scale

Sheets 1 & 2